INFRAMATION
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INFRARED TECHNOLOGY FOR PRESERVATION

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ABSTRACT

Defining the scope and specifications of historic building preservation projects can be very challenging and requires both nondestructive testing in the field and in the laboratory. In field testing, the use of infrared (IR) thermal imaging on building envelope components can provide particularly valuable information, which responds to renewed interest in energy efficiency and a new focus on moisture detection for mold prevention. In addition, infrared imaging can identify otherwise hidden changes in the structural condition of a historic building.

This paper details two different historic preservation projects: a school building built in 1919 and a mansion built in 1911, in which the use of infrared has been invaluable. The test results provided documented information on energy efficiency, moisture detection, and structural condition, which was then incorporated into the preservation project specifications.

Keywords: Infrared, thermal imaging, IR building surveys, historic preservation, historic buildings.

INTRODUCTION

All components of a building emit infrared radiation — heat that is not visible to the human eye. The infrared camera senses that infrared radiation and electronically displays a visual image of the thermal patterns. Technicians trained and certified in building diagnostics can determine from this image what components have surface heat patterns that represent conductive or convective heat loss/gain.

When buildings are imaged with infrared cameras during cold weather, with a minimum inside-outside delta T of 18 Fahrenheit degrees, the differing thermal patterns will appear depending on the age and type of construction. (Note: A building may be imaged during the summer months as long as the minimum delta T is present and the image scales will be inverted.)

This paper focuses on two wall systems. The first is a masonry barrier wall system at Withrow High School, which is more than fifty years old. The weather resistance of the walls, which consist of several vertical planes or *wythes* of masonry, is based on the ability of the brick to absorb and block rainwater. The second is located at Oldfields Estate, which embodies three eras of construction, the original house built in 1911, and additions built in 1932 and 1939. In areas of the walls, which contain elevated levels of moisture, the infrared camera detects conductive heat loss patterns to the brick exterior surface. This heat loss is associated with the lowering of the thermal resistance of the wall assembly caused by the moisture within the wall assembly. As the building was thermally imaged, locations of thermal anomalies were documented. Those anomalies that were conductive and not convective heat loss were documented for further investigation and "neutron thermalization" testing.

Pursuant to American Society of Nondestructive Testing (ASNT) “Handbook of Nondestructive Testing” Volume 3, the guidelines for a building envelope infrared inspection were followed in this inspection.

INSPECTION FINDINGS AT WITHROW HIGH SCHOOL

Findings that are common to all six building sections, A, B, C, D, E and K are as follows:

1. All buildings are very air leaky, making them unable to hold a constant interior pressure differential. When measured across the building envelope a positive pressure directly proportional to the wind was measured on the windward side. The leeward side of the building would then present a negative pressure reading. This condition was found at all three levels of the building and readings varied little throughout the building.

   During the inspection process pressure measurements were taken measuring the interior static pressure across the building envelope with the building in "normal" HVAC operating conditions. The results show an average positive pressure of 6.0 Pascal to the outside on the first floor north facing elevations (windward side). The south facing elevations (leeward side) tested an average negative pressure of 3.75 Pascal. While all of the building should operate at a positive pressure to the outside, these negative readings on the leeward side at the time of this inspection are not surprising given the age and type of building construction. However, if after restoration and installation of new HVAC equipment along with new windows and doors, the readings were to remain at these levels that would be reason for concern given the type of wall construction being examined.

2. Heat loss occurs at the soffits of all building sections. Where accessible, further testing of the wall presented no elevated levels of moisture at the time of this inspection. While it is visually clear that water has been present in these upper sections of the wall, at the time of this inspection, which should be noted is after the building has been re-roofed and all flashings, gutters and downspouts replaced, the wall sections did not have elevated moisture counts. This leads to the conclusion that this is stack effect heat loss at the stone cornice.

3. There is considerable heat loss, both conductive and convective at all the windows and doors in all six buildings. These are all scheduled for replacement. Note that some windows on the third floor of building A had been replaced and present a much-improved thermal pattern.

4. Most of the interior corners (as seen from the exterior) are warmer than the adjoining wall. Further testing for moisture in these corners did not produce a significant increase in hydrogen. Given that these are barrier walls the importance of the mortar joints cannot be overstated. The re-grouting efforts which have been completed to date are marginally effective in assuring water will be shed as quickly as possible.

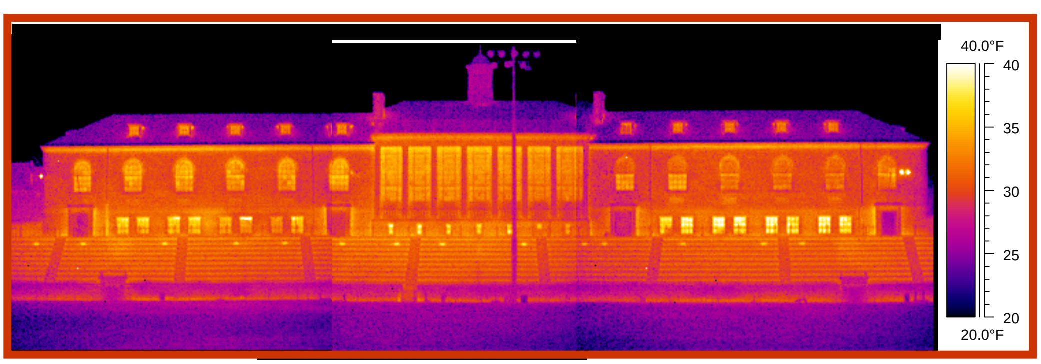

Figure 1. *Withrow High School, Building K east elevation view.*

5. On all sections except building K, the new copper downspouts had seam splits allowing them to leak. School personnel indicated that in the winter storm water would “back up” into the downspouts and then freeze. Looking at the current condition of these downspouts, this appears to be an accurate explanation for the seam splits. At the locations shown in the drawings, the moisture content tested higher around these leaking downspouts than in the adjoining wall sections.

Building K

1. Locations 1 and 2 are at the north and south entry doors on the east elevation. At these locations, along with the center two doors (all four east elevation entry doors), the thermal pattern indicated heat loss. Moisture testing produced the highest levels of hydrogen found in any of the elevations. Further investigation (see Figure 2 and 3 details) shows flashing and caulking failures at these entries.

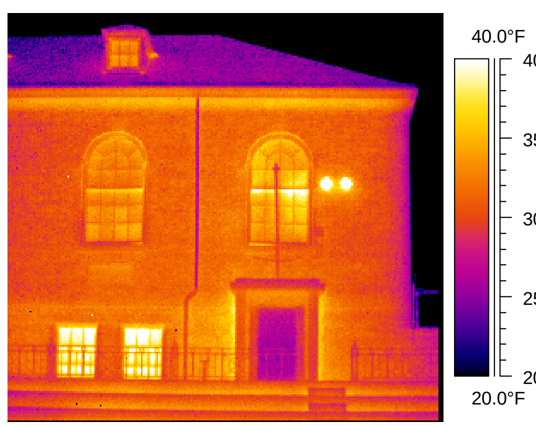

Figure 2. *Location 1, Building K, east elevation.*

Figure 3. *Location 2, Building K, east elevation.*

FINDINGS FOR OLDFIELDS ESTATE

Findings that are common to the three sections of the building with three different ages are as follows:

1. Heat loss at all windows. The windows represented the warmest of all exterior surfaces. Given the "R" value associated with windows compared to the walls of the building, this would be expected. Additional loss at the windows was seen around some window frames where lesser insulation values are necessitated by the framing for the windows and/or the frame around the window sash is exfiltrating warm air from inside the building.
2. Heat loss through walls. Based on information provided at the time of the inspection, the walls are uninsulated solid concrete or hollow clay tile block construction depending on location. This

makes the thermal images of the wall elevations more easily understood. Starting with the first floor, above basements, the solid concrete, which comprises the floors, can be seen as warmer than the wall above which includes the hollow block. The line that represents the floor between the first and second floors can also be seen as warmer for the same reason. Exterior chimneys such as those seen in the front elevation can also be seen as quite warm, an indication of heat loss. An interesting pattern appears on either side of the main entry on the east front elevation. At these locations it appears windows have been covered and/or removed. The solids, which created the arched lintels for these two windows, can be seen as warmer.

3. Heat loss into attics. A common problem to both elevations inspected was heat escaping from the conditioned building envelope into the unconditioned attics. The infrared images confirm these patterns with heat escaping from the soffit areas, around dormers and the presence of an even warm temperature throughout the roof surface.

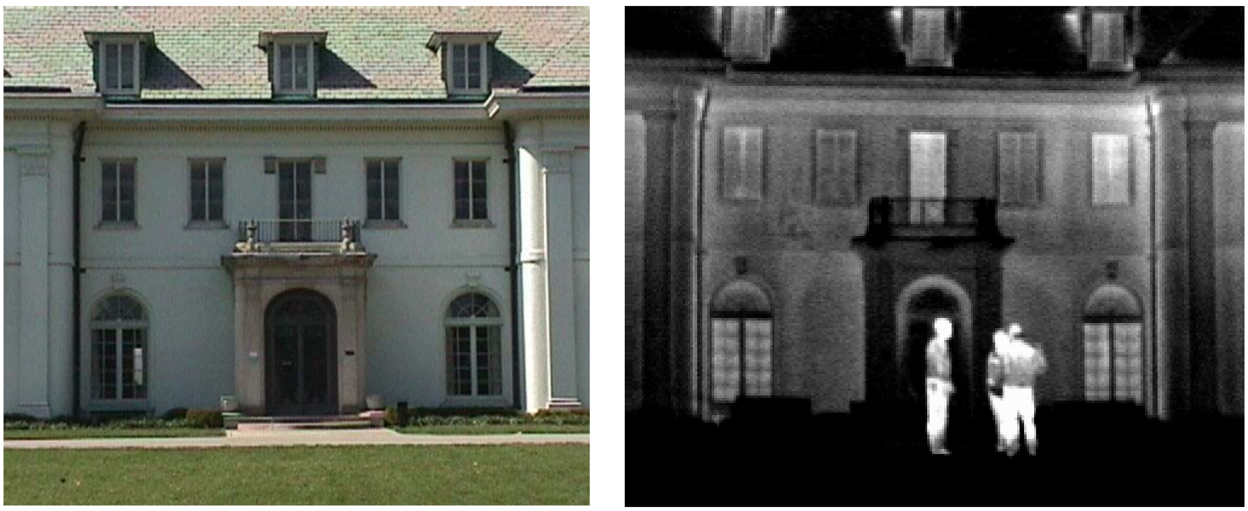

Figure 3. *Oldfields Estate, front (east) elevation. The black and white thermograph (right) shows heat loss through windows and dormers. The human figures appear warmer than the building.*

SUMMARY

At the Withrow High School, it appears that roof leaks that were the cause of the moisture damage in the plaster on many of the wall and ceiling sections throughout the building have been repaired. Testing with infrared cameras concludes that the differing thermal resistance of the subject wall materials at varying construction details is primarily the result of convective losses around windows and doors in combination with conductive losses associated with flaws in the plaster, brick and stone which combine to present thermal anomalies.

However, there are areas of moisture being retained in the barrier walls as detailed in this report. These areas become more concerning if water is allowed to continue to be introduced and the building dynamics changed. When the convective losses are lessened with new doors and windows and the HVAC system is changed from the original to a forced air system with air conditioning, these wet wall sections may not dry. The result could be brick failure over time.

In addition if the wall system is changed, the thermal resistance (R value) of the wall system along with its ability to dissipate moisture may change. Given this, it is possible that dew point temperature, the temperature at which condensation first occurs, could be achieved within the wall system during certain weather conditions. This situation could facilitate the long-term deterioration of these barrier brick and stone walls.

Oldfields Estate presented some of the same and some quite different results from Withrow High School, using the same inspection methods. In both historic preservation projects the use of non-destructive infrared imaging proved to be a valuable addition to the documentation and analysis process. Additionally, longer term monitoring of historic structures is possible through periodic infrared imaging of historic structures.

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